

Automated Serial Sectioning for 3D Reconstruction

Automation increases speed and reduces uncertainty in alignment.

John H. Glenn Research Center, Cleveland, Ohio

Figure 1 depicts some aspects of an apparatus and method for automated serial sectioning of a specimen of a solder, aluminum, or other relatively soft opaque material. The apparatus includes a small milling machine (micromiller) that takes precise, shallow cuts (increments of depth as small as 1 μm) to expose successive sections. A microscope equipped with an electronic camera, mounted in a fixed position on the micromiller, takes pictures of the newly exposed specimen surface at each increment of depth. The images are digitized, and the resulting data are subsequently processed to reconstruct

three-dimensional (3D) features of the specimen.

The micromiller includes a three-axis (x,y,z) translation table. The specimen remains mounted on the translation table during all phases of the sectioning process, including etching and imaging in addition to milling. All motions of the table during the sectioning process take place under computer control. Thus, to index to the next increment of depth, the table is translated the corresponding short distance along the z-axis. The translation table is also used to move the specimen along the y-axis from the milling posi-

tion to an intermediate etching position, then to the imaging position, then back to the milling position for the next cut.

This method affords advantages over a related prior method in which a specimen was repeatedly cut on a micromiller, then dismantled, etched, photographed through a microscope, then remounted on the micromiller for the next cut. One advantage is elimination of much of the positioning uncertainty, and hence the uncertainty in registration of features seen at different depths, that arises from repeated mounting, dismantling, and photographing at a location different from the milling location.

Another advantage is automation of alignment of the images acquired at different depths. In the prior method, images were aligned, after they were recorded, in a procedure that was at least partly manual and hence time-consuming. In the present method, alignment is performed as an integral part of processing of the image data.

Inasmuch as tests have shown that there is no measurable undesired translation of the specimen along the x-axis, the alignment problem involves mainly compensating for any error in returning the specimen, on each cycle, to the same nominal y coordinate for imaging. Measurements have shown that the actual y coordinate used for imaging on a given section can deviate from the nominal position a distance of the order of 50 μm . In the present method, during imaging, the y coordinate of the specimen is measured by use of a linear variable-differential transformer (LVDT) accurate to within 0.5 μm . Then during processing of the image data as described in the next paragraph, the measured y coordinate of imaging position for each section is used as an offset to translate the image in y to the nominal position.

Once the image data from all sections have been recorded, they can be processed by readily available image-data-processing software, then combined to construct digital representa-

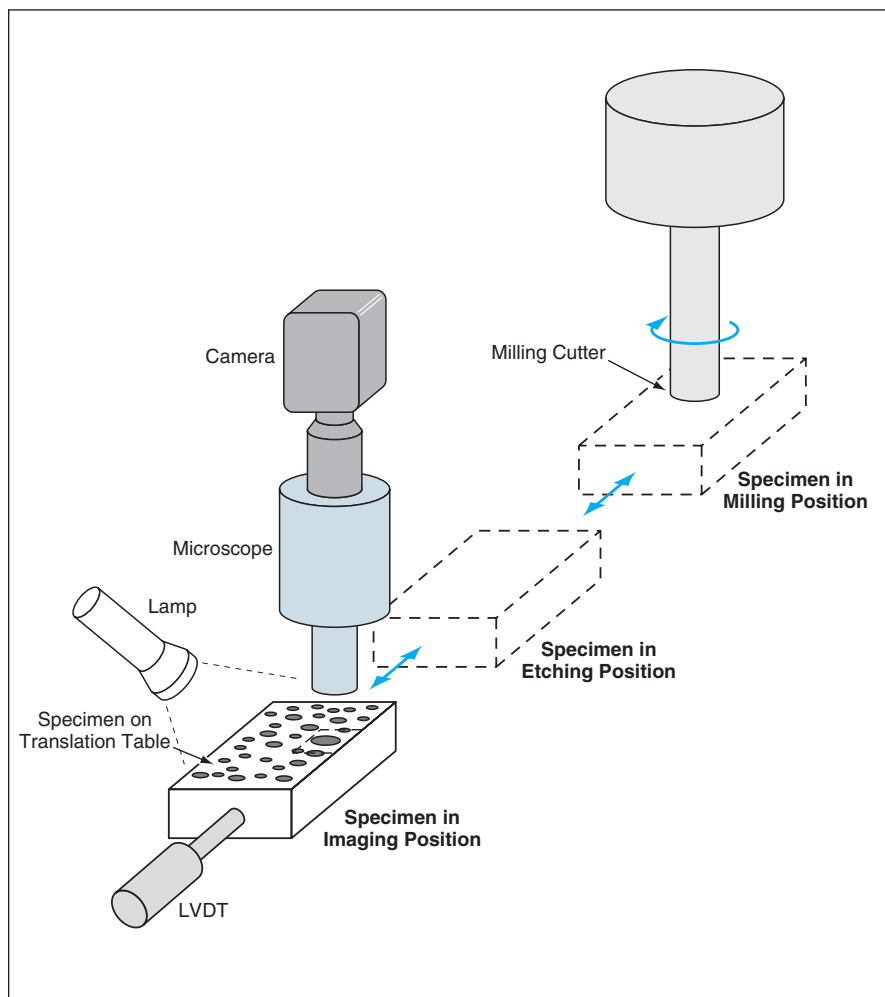


Figure 1. A Specimen on a Translation Table is moved along the y-axis among milling, etching, and imaging positions. With the help of the LVDT, the corrections for small y-axis misalignments of imaging positions can be made during processing of image data.

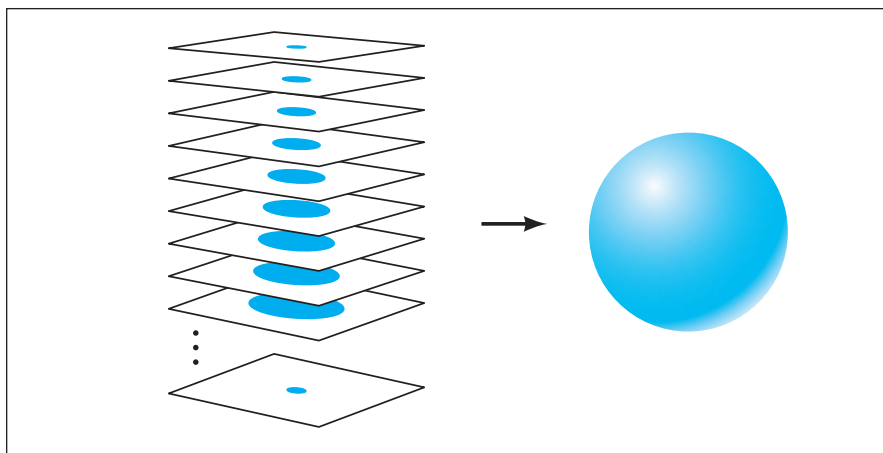


Figure 2. A **Three-Dimensional Feature** (in this case, a sphere of darker material) inside the specimen is reconstructed from cross sections taken sequentially at small increments of depth.

tions of three-dimensional features inside the specimen (see Figure 2). As a result of automation of the sectioning process, it is now possible to take about 20 sections per hour from given specimen, whereas previously, at most 10 sections could be taken in a day.

*This work was done by Jen Alkemper and Peter W. Voorhees of Northwestern University for **Glenn Research Center**. Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16820.